Electric Vehicle Implementation in Rural New Hampshire

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Executive Summary

The Capstone project integrated my professional work with my expertise developed during matriculation in the Energy Policy and Climate program at Johns Hopkins University. Professionally, I am a regional planner in the Upper Valley Region of New Hampshire where my primary work is focused on Geographic Information Systems (GIS) and transportation planning. This Capstone integrated the geography of where I work combined with rural transportation. My professional work involves assisting rural communities with various tasks and projects and understanding the uniqueness of the bi-state region of Vermont and New Hampshire, seasons, geography, and lifestyle in rural municipalities. I often work with local governments in planning for the future and creating a vision of what that future could look like.

I benefitted from the Capstone experience because I was able to use my expertise from matriculation at Johns Hopkins University to take my professional work a step farther. My professional work allows me to collect data and to come up with action plans for the future. The Capstone helped bridge the gaps by allowing me to also analyze the data and come up with recommended policies.

I was able to learn more about my community and the topic of electric vehicles (EVs) in a more in depth way. I learned that the rural challenge of EVs is becoming less of a challenge as more make and models are becoming available. The analysis of commuter data put into perspective the way people move around the region is important to how consumers think about transportation. EVs in my professional work have been viewed as futuristic and not a transition that would likely happen in the region. After this Capstone experience, I am encouraged to

change that mentality as there are EVs available that could support and are feasible to purchase for many commuters and residents.

Overall, this Capstone experience and my courses at Johns Hopkins University have helped bridge the gap between my professional work and my expertise. The benefits from this project will go beyond my time at Johns Hopkins University and will be a guide to the City of Lebanon and surrounding communities going forward.

Introduction

Electric Vehicles (EVs) are no longer a technology of the future. With recent innovations in technology, many states, municipalities, and community organizations are beginning to talk about EVs and EV charging equipment. Compared to gas-powered vehicles, EVs are fuel efficient, pollute less, and have significant fuel cost savings. Many states and large cities in the United States have already taken initiative by investing in EV charging equipment, converting fleets, and/or providing incentives to residents for personal EV use. EV implementation in large fleets and densely populated areas has been successful.

Transitioning to EVs in rural environments is a different type of challenge. In rural areas, people are more spread out and commuting miles are greater to get to jobs. EV research and technologies are continually improving and there are current makes and models available that could suit rural commuting range. Battery technologies have improved to account for differing temperatures and market competition is bringing prices down. Rural municipalities can approach EV related challenges of supporting and promoting growth in EVs sales through investment in EV technology, transitioning fleets to EVs, and investing in infrastructure.

This paper focuses on the feasibility of investing in EV technologies in the rural Upper Valley Region of New Hampshire, and explores how a municipality could accomplish this goal with a focus on the City of Lebanon. This paper will address the EV makes and models that are viable in this geography and seasonality, and can support the movements of rural commuters. This paper will also review the potential benefits for investment in charging equipment to support a transition to EVs and conclude with a proposed action plan for rural communities to invest in EV technologies.

Global EVs

A worldwide transition to electric vehicles is motivated by environmental and economic benefits. Environmental benefits include reduced greenhouse gas emissions from the tailpipe in the transportation sector which improves air quality and mitigates climate change. Internal combustion engine (ICE) vehicles, also known as gas-powered vehicles, produce tailpipe emissions whereas EVs have zero tailpipe emissions (U.S. Department of Energy: Alternative Fuels Data Center 2018). While EVs have zero tailpipe emissions, they are not completely zero emission vehicles due to the emissions that come from the production of electricity in this country. EVs currently produce 54% less greenhouse gas emissions throughout the life of the vehicle than ICE vehicles (Drive Change Drive Electric 2018). Other than reducing greenhouse gas emissions, a transition to EVs stands to reduce fossil fuels used for transportion which would reduce greenhouse gas emissions and environmental harm from the extraction, production, and transport of oil and fossil fuels (U.S. Department of Energy: Alternative Fuels Data Center 2018).

Globally, an increase in EV sales including electric transit buses is estimated to displace 7.3 million barrels of oil per day (Bloomberg New Energy Finance 2018). In addition to the global benefits, economic benefits include a reduced dependency on oil and fossil fuels for transportation, in particular, reducing national dependency on foreign oil. Smaller scale economic benefits include reduced fuel and maintenance costs for vehicle owners.

Global EV sales are estimated to increase rapidly by 2040, with 55% of new vehicle sales predicted to be EVs with China as the leader (Bloomberg New Energy Finance 2018). EV sales have been increasing for a number of reasons. One reason is that lithium-ion battery prices have dropped about 79% from 2010-2017 with energy density within the batteries increasing about 5%-7% per year (Bloomberg New Energy Finance 2018). Some other reasons are related to government policies and fuel standards including China's 'New Energy Vehicle' quota forcing automakers to build EVs and Europe's diesel bans and air quality concerns bringing more focus to EVs and transportation. Lastly, automakers are seeing this shift as an opportunity to get ahead and with the policies pushing from one end, competition in the market is a reason many have aggressive plans for the future of EVs (Bloomberg New Energy Finance 2018).

Challenges

While there are many reasons for EV sales to increase over the next few decades, this increase will come with some challenges. A challenge will be scaling up battery production to keep up with sales. Materials used to make the lithium-ion batteries used in EVs include cobalt, lithium, and nickel. Prices for these materials have increased with demand, presenting a financial challenge to EVs (Bloomberg New Energy Finance 2018). Cobalt resources are hard to find and shortages are predicted to occur as early as 2020 (Bloomberg New Energy Finance 2018). This is a potential risk to EV sales and manufacturing unless other technologies to supplement the loss of cobalt and cost of materials are identified.

Another challenge that all states are facing is the loss of income from the gas tax due to the reduced purchase of gasoline by EV drivers. All states have a gas tax that is used to fund a portion of the transportation sector. In New Hampshire Fiscal Year 2016, revenue from the motor fuels or gas tax amounted to $182.6 million. Approximately $123.6 million went to the State's unrestricted Highway Fund for road maintenance and construction (Sletten 2017). If more people are driving EVs, that means less people are purchasing gasoline and not paying the gas road tax and in turn revenue for roads is decreasing. A “vehicle miles traveled (VMT)” tax or fee is a potential way of charging both ICE vehicles and EVs in the same manner. The practice would be that drivers would be charged a fee based on the number of road miles they drive regardless of the type of vehicle (RAND Corportation 2011).

State Level

At the time of this writing there are a few Federal Policies that could favor a transition to EVs. The primary policy is the Federal Tax Credit that is available for most EV makes and models of up to $7500 (FuelEcoconmy.Gov 2018). Many states in the U.S. have developed strategies and policies to manage a transition to EVs. Examples of various strategies and states that have adopted them are seen in Figure 1.

State Strategies for EVs		
Strategy	**Number of states that adopted strategy**	**Examples**
Licensing, Registration, or Road Use Fees or Discounts	22	Washington - special EV fee at registration that will be used fund future EV charging equipment
		Connecticut - reduced registration fee for EV vehicles to incentivize more personal EV use.
Financial Incentives for EV Purchase	23	Massachusetts- rebate program of up to $2,500 to customers purchasing or leasing EVs or zero emissions motorcycles
Driving Incentives- HOV Lane Access or Designated Parking Spaces	13	New York - allows EVs in the HOV lane regardless of occupancy inside the vehicle.
Emissions Test Exemptions	14	Rhode Island - EVs are exempt from State Emissions Inspections which saves the vehicle owner money on inspection
Grants, Rebates, Financing, or Loans for EV Charging Equipment	27	Washington D.C. - provides a tax credit for 50% of the purchase cost for EV charging equipment
Utility Incentives	13	Nevada - utility company offers discounted rates to customers that charge EVs during off-peak hours
Vehicle Fleet Requirements and Goals for Government Fleets	28	Oregon - requires all state agencies and transit companies to acquire alternative fuel vehicles for all vehicles and to report on vehicle emissions annually
		New Hampshire - must pursue EVs for state fleets and provide charging equipment at state offices with more than 50 employees

Figure 1: States Strategies (National Conference of State Legislatures 2017)

New Hampshire

In New Hampshire, there are 530,000 registered vehicles and only about 1,400 are EVs which is less than 1/3 of one percent of total registered vehicles (Plug In America May 2017). New Hampshire's 10-Year State Energy Strategy briefly mentions EVs and EV infrastructure in regard to transportation (New Hampshire Office of Strategic Initiatives 2018). The Strategy discusses energy intensity in regard to vehicle miles traveled and the behavior of New Hampshire drivers. The State's Strategy stresses that consumer behavior results in energy consumption more-so than the "equipment they are operating". For example, a more fuel efficient vehicle may allow for a driver to drive more miles at the same consumption of gasoline as a less efficient vehicle. The Strategy supports continued improvement in energy intensity of passenger-miles, but will only spend non-taxpayer dollars to support these improvements. The State believes that although EV sales will increase, they will still remain a minor fraction of the fleet. The investment of only non-taxpayer dollars is due to avoiding benefitting a small portion of the population (New Hampshire Office of Strategic Initiatives 2018).

New Hampshire and Volkswagen

On January 4, 2016 the United States filed a complaint against Volkswagen alleging violations of the Clean Air Act. It was alleged that approximately 580,000 Volkswagen manufactured diesel vehicles model years 2009-2016, were emitting nitrous oxide (NOx) beyond the Federal standard. Volkswagen deliberately added a 'defeat device' to these vehicles that allowed these vehicles to pass through emissions testing without actually following emissions standards (New Hampshire Department of Environmental Services 2018).

On June 28, 2016 and finalized in October 2016, Volkswagen entering into a Partial Consent Decree agreement to address the high emissions 2.0 liter vehicles on the road and to address the environmental consequences of emissions from these vehicles. The agreement requires Volkswagen to invest $2 billion over 10 years to actions that support technology for Zero Emissions Vehicles (ZEVs). They are required to invest $1.2 billion of this money outside of California. Volkswagen is also required to establish an environmental mitigation trust of $2.7

billion that is separate from the $2 billion for technology and ZEVs. The environmental mitigation trust will be available for states involved in the trust to reduce NOx in areas where the offending vehicles were operating through efforts decided on by each state. The agreement also requires Volkswagen to develop and implement a program where they will buy-back purchased vehicles, terminate leases without penalty, or modify vehicles to meet standards; the goal being to remove or modify 85% of the 2.0 liter vehicles prior to June 30, 2019 with an estimated cost is around $10 billion.

In December 2016, a similar agreement was made in reference to 3.0 liter diesel engine vehicles adding an additional $225 million to the environmental mitigation trust (New Hampshire Office of Strategic Initiatives 2018).

The State of New Hampshire was allocated $30.9 million from the environmental mitigation trust, which it accepted through the courts in late 2017. The State of New Hampshire created a Beneficiary Environmental Mitigation Plan to explain how the funds would be spent which was approved in September 2018. New Hampshire has allocated 15% or approximately $4.6 million to the acquisition, installation, operation and maintenance of EV charging equipment (State of New Hampshire 2018). Approximately 70% or $21.7 million is allocated to upgrade diesel vehicles to cleaner fuels that can include EVs and supporting equipment (State of New Hampshire 2018).

City of Lebanon

The City of Lebanon, New Hampshire is a rural city of approximately 13,000 residents located on the Connecticut River bordering Vermont. Lebanon is known for being the home of the State’s largest employer Dartmouth-Hitchcock Medical Center, and proximity to nearby

Dartmouth College. The City of Lebanon currently has no policies in place that support a move to EVs but they have documents that promote the transition. The City Council approved a Resolution in support of the Paris Climate Agreement and the New Hampshire Climate Action Plan, both efforts to significantly reduce greenhouse gas emissions (City of Lebanon 2017).

Additionally, Lebanon's Master Plan discusses EVs both in the Energy Chapter and the Transportation Chapter. The Master Plan supports integrating EV charging equipment into City planning (City of Lebanon 2012).

Data

Registered Drivers

According to New Hampshire Department of Motor Vehicles, the number of registered full EVs in the New Hampshire jumped from 564 in 2016 to 771 in 2017. In Grafton County, where Lebanon is located, registered EVs went from 48 in 2016 to 62 in 2017. Grafton County is number 5 out of 10 counties for number of registered EVs. In Lebanon there were 8 battery electric vehicles (BEVs) and 10 plug-in hybrid electric vehicles (PHEVs) registered in 2017 (New Hampshire Department of Motorvehicles 2017). BEVs run solely on batteries powered by electricity while PHEVs run on batteries powered by electricity with a shorter range and have a back-up ICE that is gas powered for further range. Figure 2 shows the total number of BEVs and PHEVs registered in other New Hampshire municipalities that have residents that commute to Lebanon. This table shows that most municipalities that have workers commuting to Lebanon have at least one EV registered. This shows that people who drive EVs can live anywhere and Lebanon's investment in EVs could prove well for commuters coming in to Lebanon for work.

Cities like Nashua, Keene, and Manchester with larger populations than Lebanon have seen successes in EV registrations that could set an example for Lebanon's future with EVs.

Total Number of Electric Vehicles Registered in City/Town					
	BEV	**PHEV**		**BEV**	**PHEV**
Lebanon	8	10			
Claremont	1	0	**Hanover**	18	32
New London	8	8	**Plainfield**	5	6
Plymouth	2	1	**Piermont**	0	2
Haverhill	1	1	**Orford**	1	2
Charlestown	1	4	**Lyme**	3	3
Littleton	1	3	**Dorchester**	0	0
Concord	10	54	**Orange**	0	1
Manchester	27	50	**Grantham**	2	14
Franklin	0	5	**Cornish**	1	2
Nashua	52	76	**Croydon**	0	0
Keene	12	81	**Canaan**	1	5
Enfield	4	5	**Grafton**	0	0

Figure 2: Number of Electric Vehicles Registered in City/Town (New Hampshire Department of Motorvehicles 2017)

There were a total of 14,680 vehicles registered in Lebanon in 2017 with a majority being passenger vehicles (City of Lebanon, New Hampshire 2017). The national average for registered EVs in 2017 is 1.2% (EV Adoption 2018). New Hampshire's neighbors Massachusetts and Vermont surpass the national average with 1.35% and 2.13% respectively in 2017 (EV Adoption 2018). New Hampshire, however, is below the national average at 0.89% while Lebanon is far below at 0.1% (EV Adoption 2018).

The 2016 American Community Survey estimates that there were 6,990 workers over the age of 16 in Lebanon that year. Out of all workers in the City, 6,033 (86%) were identified as having commutes where they ride in a car to work either alone or in a carpool (US CENSUS: American Community Survey 2016).

Commuter Data

Lebanon is the center point for the Census Lebanon New Hampshire – Vermont (NH-VT) MicroNECTA (Micro New England City and Town Area). U.S. Census and American Community Survey data for Lebanon are based on the New Hampshire Portion of the MicroNECTA. The New Hampshire municipalities include Piermont, Orford, Lyme, Dorchester, Hanover, Canaan, Orange, Enfield, Grafton, Plainfield, Grantham, Cornish, Croydon, and Lebanon (see Figure 3). Lebanon is at the center of the MicroNECTA and has the largest population and employment centers as well as location along Interstate 89 and other major State connector routes (New Hampshire Employment Security 2010).

Many people commute into, out of, or through Lebanon daily to get to work. In 2010, Lebanon had an estimated day-time population of 25,000-35,000 including commuters, patients, shoppers, and others traveling into the City (Lebanon MP). An estimated 19,835 commuters roughly 56%, live and work within the NH Portion of the Lebanon NH-VT MicroNECTA. That means roughly 44% come from outside of the NH portion of the MicroNECTA. Figure 4 shows where people commute in from and where residents from Lebanon travel to work. The figures show that out of the commuters coming into the region for work, about 60% are coming from the State of Vermont. As Lebanon is a border City, the data used to calculate commuter range will be from New Hampshire (New Hampshire Employment Security 2010).

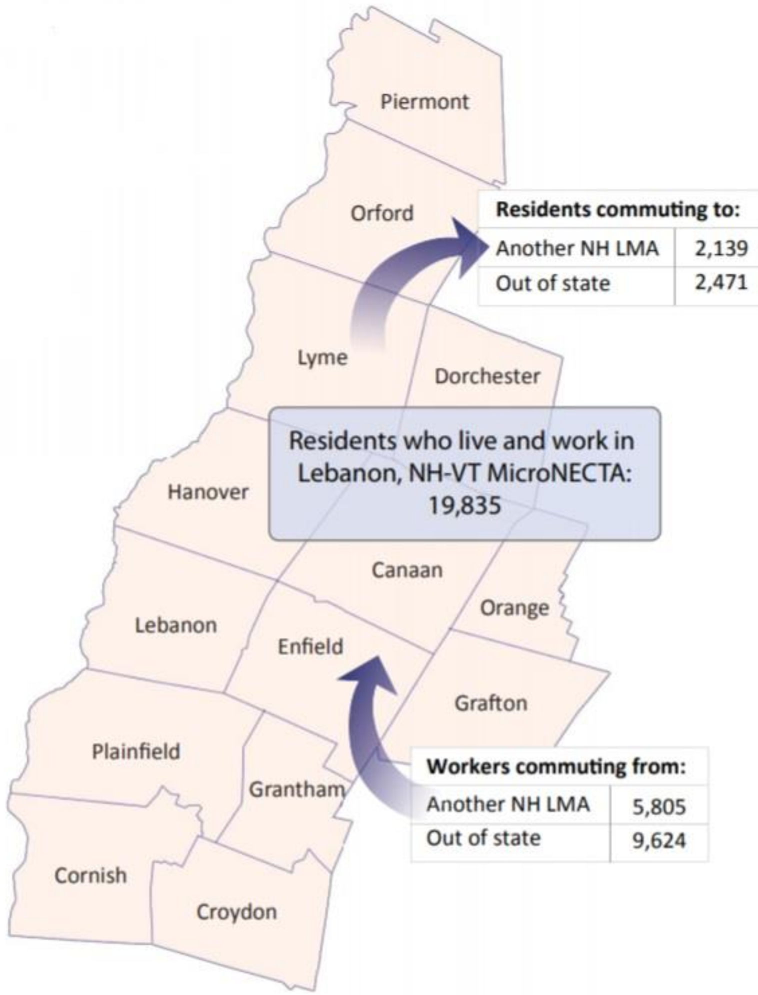

Figure 3: NH Portion of the Lebanon NH-VT MicroNECTA (New Hampshire Employment Security 2010).

Commuting Patterns of Workers that Live or Work in the NH Portion of the Lebanon NH-VT MicroNECTA		
Description	**Commute In**	**Commute Out**
Commuters traveling to work in the Lebanon NH MicroNECTA	15,429	N/A
Residents commuting to work outside of Lebanon NH MicroNECTA	N/A	4,610
Other NH Labor Market Areas	5,805	2,139
Claremont-Newport NH LMA	1,978	722
New London NH LMA	875	255
Plymouth NH LMA	643	421
Haverhill NH LMA	593	143
Charlestown NH LMA	388	37
Littleton NH-VT LMA, NH Portion	328	98
Concord NH MicroNECTA	288	160
Manchester NH MicroNECTA	193	98
Franklin NH LMA	162	11
Nashua NH-MA NECTA Division, NH Portion	103	33
Dover-Durham NH-ME MetroNECTA, NH Portion	61	N/A
Hillsborough NH LMA	31	12
Conway NH-ME LMA, NH Portion	29	N/A
Haverhill-Newburyport-Amesbury MA-NH NECTA Division, NH Portion	27	6
Meredith NH LMA	23	N/A
Lawrence-Methuen-Salem MA-NH NECTA Division, NH Portion	15	N/A
Portsmouth NH-ME MetroNECTA, NH Portion	14	20
Laconia NH MicroNECTA	13	14
Keene NH MicroNECTA	12	57
Belmont NH LMA	8	19
Berlin NH MicroNECTA	8	N/A
Peterborough NH LMA	7	N/A
Colebrook NH-VT LMA, NH Portion	6	N/A
Lowell-Billerica-Chelmsford MA-NH NECTA Division, NH Portion	N/A	18
Raymond NH LMA	N/A	6
Surrounding States	9,624	2,471
Maine	21	5
Massachusetts	187	115
Vermont	9,247	2,147
Other US States/areas	169	204

Figure 4: Commuting Patterns of Workers that Live or Work in the NH Portion of the Lebanon NH-VT MicroNECTA (New Hampshire Employment Security 2010)

Figure 5 compares commuting data across select LMAs in the State. The Lebanon MicroNECTA is unique in that it has the most commuters coming from out of state and the second lowest percentage of residents living and working in the labor market. Having a high percentage of commuters traveling to the Lebanon MicroNECTA from out of state could be a result of Lebanon's location on the Vermont border. Lebanon is also located at the nexus of the interchange between I91 and I89 in which many commuters from Vermont would travel through to get to workplaces in Lebanon. For example, at Lebanon's largest employer Dartmouth-Hitchcock Medical Center, approximately 24% of employees live in Vermont (Dartmouth-Hitchcock 2018). That is a significant differentiator to the labor market of this region.

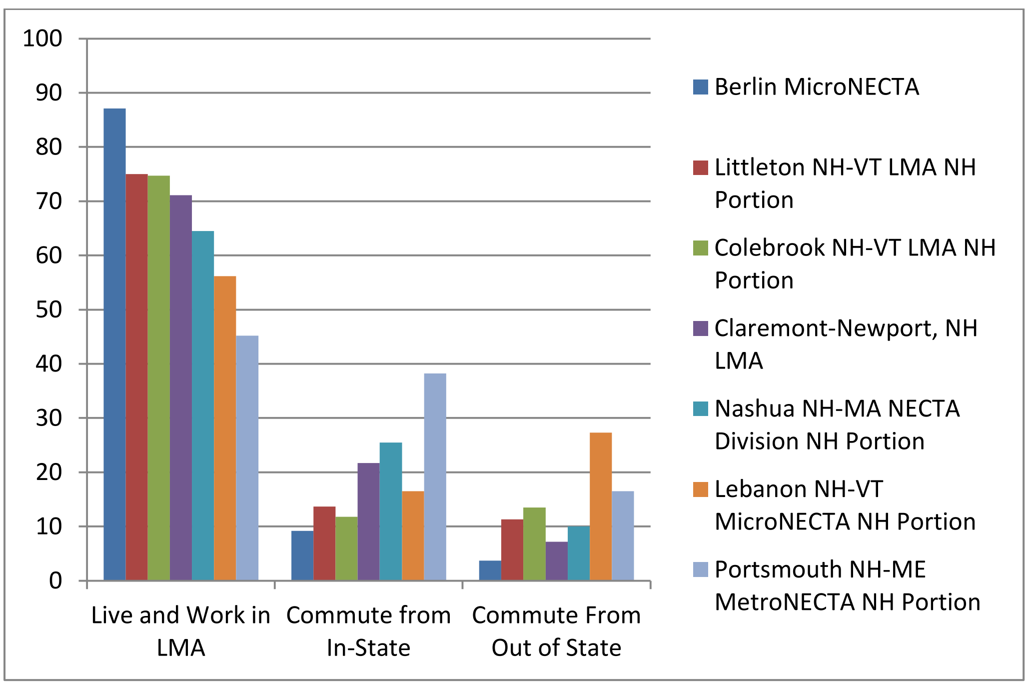

Figure 5: Commuters that work in each market area (New Hampshire Employment Security 2010)

Charging Equipment

There are many options for type of charger, varying in voltage, cost, and charging time, available for each option. Most customers are expected to prefer the shorter charging time for highway stops and retail outlets while cheaper longer charging times would be suitable for park and rides and places of employment. The three common types of charging equipment are Level 1 chargers, Level 2 chargers, and DC Fast Chargers.

Level 1 chargers are the least expensive out of the three types. Level 1 chargers take longer to charge and are best used when recharging a battery overnight as a full charge could take between 12-18 hours for a larger battery. Level 2 chargers have a shorter charging time than Level 1 chargers and are more expensive. It typically takes about 4-6 hours for a larger battery to reach a full charge making Level 2 chargers good for employees or for partial charges at shopping centers. DC Fast chargers are the fastest and most expensive charging equipment available and can often charge a large battery in less than an hour. These chargers would be best at rest areas along Interstates or for other short stops. For more information regarding charging types see Figures 6 and 7 (ChargeHub 2018).

EV Charging Basics

Type	Miles of Range Per Hour of Charging (RPH)	Time to Fully Charge	When to Use	Connector
Level 1, Standard Wall Outlet (AC)	5 RPH	+ 16 hours for an 80-mile battery + 40 hours for a 200-mile battery	+ Get some charge while you sleep Note: slower for cars with large batteries	Note: you'll need your own cable to plug in to the wall for Level 1
Level 2 Charging Station (AC)	+ 12 RPH for cars with 3.7 kW on-board charger + 25 RPH for cars with 6.6 kW on-board charger	+ 3.5 hours for an 80-mile battery + 8 hours for a 200-mile battery	+ At work + While you sleep + Topping up around town	J1772 connector
DC Fast Charging	100 RPH or more, depending on the power level of the charger + 24 kW (up to 100 RPH) + 44 to 50 kW (up to 200 RPH)	Depends on the power level of the charger and car model, but could be 80% charged within 30 minutes	+ Short stops + Express Corridor locations	SAE Combo (CCS) CHAdeMO Tesla

Figure 6: EV Charging Basics (ChargeHub 2018)

Type	Voltage	Charging time		Estimated cost of unit
		Battery EV (larger battery)	Plug in Hybrid (smaller battery)	
Level 1 Charger	120 volts	12-18 hours	6-8 hours	$0 - $1000
Level 2 Charger	240 volts	4-6 hours	2-4 hours	$400 - $10,000
DC Fast Charger	480 volts	15-60 minutes	n/a*	$20,000 - $50,000

*Current PHEV models do not fast charge, but vehicle landscape is quickly evolving, may become more common

Figure 7: EV Charging Basics 2 (ChargeHub 2018)

The States of Vermont and Massachusetts have 487 and 1,636 public charging outlets respectively (U.S. Department of Energy 2018). Vermont has 78 charging outlets per 100,000 people and Massachusetts has 25 charging outlets per 100,000 people (United States Census 2010). The State of New Hampshire has 199 charging outlets (U.S. Department of Energy 2018), 15 per 100,000 people (United States Census 2010), many fewer than neighboring states. Figure 8 shows an overview of the EV charging station locations in the three states. Note the density of charging equipment around the largest cities in each state: Burlington, Vermont, Boston, Lowell, and Worcester, Massachusetts; Concord, Manchester, and Nashua, New Hampshire. Also note the gap in density between the Concord, NH area and Burlington, VT. At the center of that gap, with some increased density, is the Lebanon area.

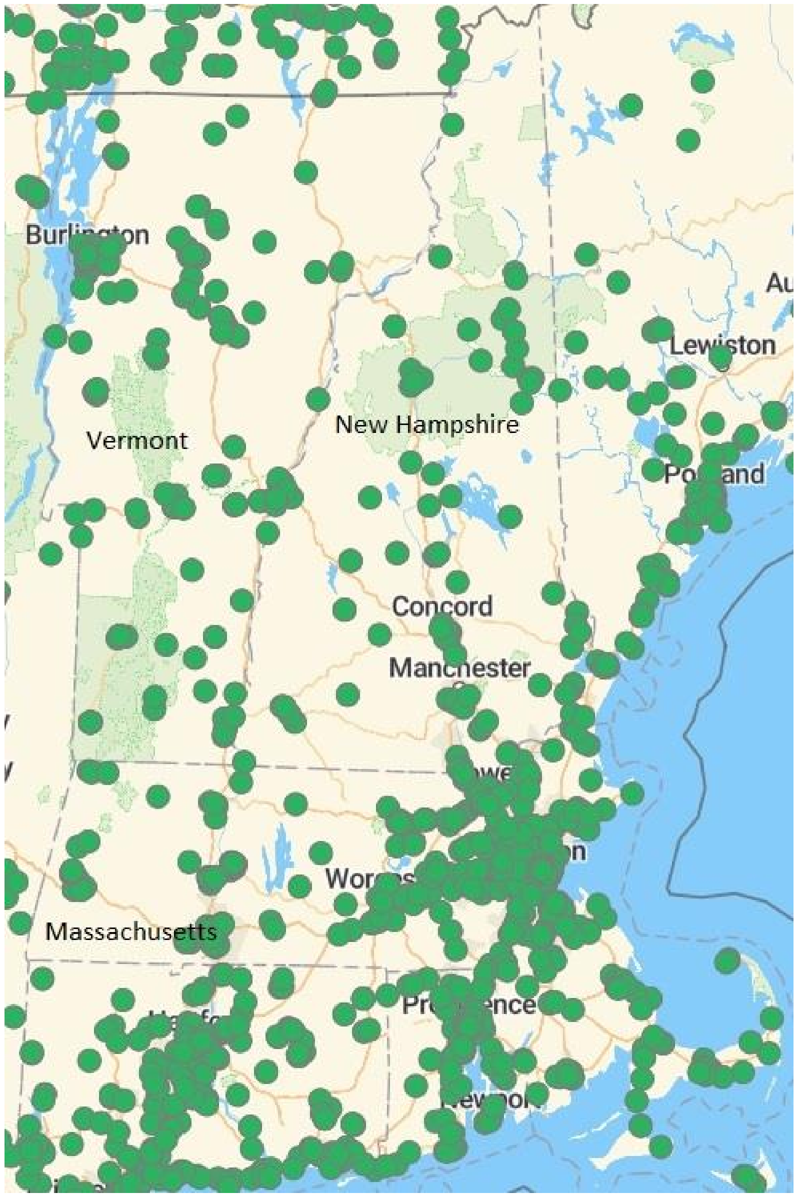

Figure 8: Electric Vehicle Charging Stations in Massachusetts, New Hampshire, and Vermont (U.S. Department of Energy 2018)

The vast difference is because both Vermont and Massachusetts have more policies that support EVs both in purchases and infrastructure. Massachusetts has many more chargers than Vermont as well because it has a policy focused specifically on EV charging equipment. The list below names the various policies in each of the three states (National Conference of State Legislatures 2017). Policies marked with a "*" include EV charging stations.

New Hampshire

- State Agency PEV and EV Procurement*

Massachusetts

- AFV and Infrastructure Grants*
- EV Emissions Inspection Exemption
- PEV and EVSE Grants*
- PEV Discounts
- PEV Rebates
- Public EVSE Requirements*
- State Hybrid EV and AFV Acquisition Requirements
- Workplace EVSE Grants*
- ZEV Parking Space Regulations

Vermont

- AFV Acquisition Requirements
- EV rebate
- PEV Credit
- State Energy Plan Transportation Requirements*

There are currently three public EV charging stations in the City of Lebanon with a total of 13 charging outlets. There are four Level 2 charging outlets (see Figure 6 and 7) at the largest employer Dartmouth- Hitchcock Medical Center, which serve employees and patients. There is one Level 2 charging outlet at Team Nissan North vehicle and service center which serves employees and customers. There are eight Tesla DC Fast Charger charging outlets in the Valley Square Shopping Center in West Lebanon which serve employees and customers of the businesses in the shopping center. Figure 9 shows a map of public charging stations in the City. This data does not include private chargers at residences or business (U.S. Department of Energy 2018).

Figure 9: Map of Charging Stations in Lebanon, New Hampshire

Vehicle Data

Figure 10 describes the cumulative sales of BEVs and PHEVs in the U.S. from December 2010 to November 2018 (Argonne National Laboratory 2018). The red bar on the graph shows new sales. It shows that the rate of sales has increased and that sales are continuing to increase each month and have not leveled off or become constant. Figure 11 describes the increase in number of BEVs by make and model sold in the U.S. over the past three years. This shows that drivers are not just interested in PHEVs and full BEVs are being sold in increasing numbers. Tesla models are the most favored over these years with a drastic increase corresponding with Tesla's release of the Model 3 (Inside EVs 2018).

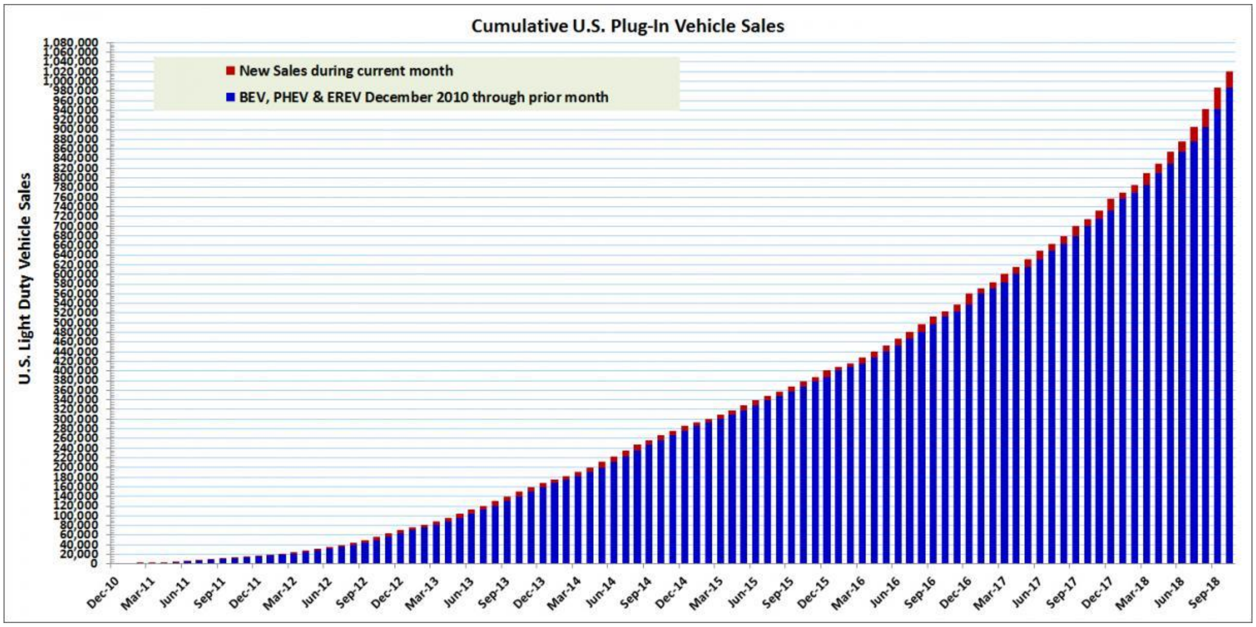

Figure 10: Cumulative U.S. Plug-in Vehicle Sales (Argonne National Laboratory 2018)

Number of Electric Vehicles Sold in the U.S.			
Make/Model	**2016**	**2017**	**2018***
Tesla Model S	28,896	27,060	19,745
Cheverolet Bolt EV	579	23,297	13,882
Tesla Model X	18,223	21,315	18,800
Nissan LEAF	14,006	11,230	11,920
Fiat 500e	5,330	5,380	1,909
Volkswagen e-Golf	3,937	3,534	902
Kia Soul EV	1,728	2,157	1,019
Ford Focus Electric	901	1,817	558
Tesla Model 3		1,764	95,882
Honda Clarity BEV		1,121	1,003
Mercedes B250e	632	744	134
smart ED	657	544	997
Hyundai IONIQ EV		432	287
Cheverolet Spark EV	3,035	23	
Mitsubishi i-MiEV	94	6	
TOTAL	78,018	100,424	167,038
*totals for 2018 only include months from January through October.			

Figure 11: Number of Electric Vehicles Sold in the U.S. (Inside EVs 2018)

Analysis

Commuter Range

The following analysis seeks to identify the distances that commuters might be traveling to and from Lebanon. Estimates of average commute miles from the municipal center of each municipality listed as the Labor Market center to the center of the City of Lebanon were used for analysis. Mileage was estimated using Google Maps directions. The estimated miles traveled one-way and roundtrip from each location can be seen in Figure 12. These calculations were derived from New Hampshire locations only. Even though more commuters come from Vermont rather than within the State of New Hampshire, the average for New Hampshire only will be used. The last two columns in the table describe the percentage of commuters coming from or going to each labor market area. For example 34.07% of New Hampshire commuters coming from the Claremont-Newport NH LMA travel approximately 23.2 miles to get to work with an estimated 46.4 miles round trip. Also, 33.75% of Lebanon NH-VT MicroNECTA (NH Portion) residents that commute out of the labor market area are traveling to work in the Claremont-Newport NH LMA. These commuters travel approximately 23.2 miles one-way and 46.4 miles round-trip.

Estimated Mileage of NH Commuters Commuting Into or Out of the NH Portion of the Lebanon NH-VT MicroNECTA				
Labor Market Area	**Miles One-Way**	**Miles Roundtrip**	**% Commuters coming from LMA in New Hampshire**	**% Commuters commuting to LMA in New Hampshire**
Claremont-Newport NH LMA	23.2	46.4	34.07%	33.75%
New London NH LMA	25.7	51.4	15.07%	11.92%
Plymouth NH LMA	40.4	80.8	11.08%	19.68%
Haverhill NH LMA	39.5	79	10.22%	6.69%
Charlestown NH LMA	34.9	69.8	6.68%	1.73%
Littleton NH-VT LMA, NH Portion	84.8	169.6	5.65%	4.58%
Concord NH MicroNECTA	59.6	119.2	4.96%	7.48%
Manchester NH MicroNECTA	72	144	3.32%	4.58%
Franklin NH LMA	46.2	92.4	2.79%	0.51%
Nashua NH-MA NECTA Division, NH Portion	88	176	1.77%	1.54%
Dover-Durham NH-ME MetroNECTA, NH Portion	96.5	193	1.05%	
Hillsborough NH LMA	52.2	104.4	0.53%	0.56%
Conway NH-ME LMA, NH Portion	56.5	113	0.50%	
Haverhill-Newburyport-Amesbury MA-NH NECTA Division, NH Portion	102	204	0.47%	0.28%
Meredith NH LMA	52.2	104.4	0.40%	0.42%
Lawrence-Methuen-Salem MA-NH NECTA Division, NH Portion	97.6	195.2	0.26%	
Portsmouth NH-ME MetroNECTA, NH Portion	112	224	0.24%	0.94%
Laconia NH MicroNECTA	56.3	112.6	0.22%	0.65%
Keene NH MicroNECTA	64.6	129.2	0.21%	2.66%
Belmont NH LMA	57.2	114.4	0.14%	0.89%
Berlin NH MicroNECTA	126	252	0.14%	
Peterborough NH LMA	72	144	0.12%	
Colebrook NH-VT LMA, NH Portion	127	254	0.10%	
Lowell-Billerica-Chelmsford MA-NH NECTA Division, NH Portion	106	212		0.84%
Raymond NH LMA	84.7	169.4		0.28%

Figure 12: Estimated Mileage of NH Commuters Commuting Into or Out of the NH Portion of the Lebanon NH-VT MicroNECTA (New Hampshire Employment Security 2010)

Figure 13 shows the breakdown of estimated one-way and round-trip mileage for commuters living and working within the NH Portion of the Lebanon NH-VT MicroNECTA. Estimated mileage was calculated using Google Maps Directions from the municipal center of the municipalities listed below to the largest employer in the City of Lebanon, Dartmouth-Hitchcock Medical Center. Residents traveling from Piermont to Lebanon have a round trip travel of about 59.6 miles.

Estimate Mileage of NH Municipalities in the Lebanon NH-VT MicroNECTA commuting to Lebanon's Largest Employer		
Municipality within the NH Portion of the Lebanon NH-VT MicroNECTA	**Average One-way Distance in miles to largest employer in the City**	**Average Round-Trip Distance in miles to largest employer in the City**
Hanover	2.9	5.8
Lebanon	4.3	8.6
Enfield	9.8	19.6
Lyme	13.2	26.4
Plainfield	13.2	26.4
Grantham	15.8	31.6
Canaan	17.3	34.6
Orange	19.1	38.2
Croydon	20.6	41.2
Orford	22	44
Cornish	23	46
Grafton	24.9	49.8
Dorchester	25.9	51.8
Piermont	29.8	59.6

Figure 13: Estimated Mileage of NH Municipalities in the Lebanon NH-VT MicroNECTA Commuting to Lebanon's Largest Private Employer

Battery Electric Vehicles and Range

Figure 14 lists the full BEV models that are available in the US listed from the shortest range to the longest range (Drive Change. Drive Elecric 2018). Comparing Figure 14 to the one-way and round trip miles in Figure 12, all commutes within New Hampshire traveling into or out of the NH Portion of the Lebanon NH-VT MicroNECTA could be supported by currently available BEVs. While commuters traveling the farther distances would have less BEV options, there is still at least one BEV option that would support the necessary commuting range. Commuters with the longest one-way commute of 127 miles to Colebrook could be supported by nine out of the sixteen vehicles listed.

Make/Model	Range	Cost Base MSRP (does not include Federal Tax Credit)	AWD option
smart ED	58	$ 25,290	FWD
BMW i3s	107	$ 47,650	RWD
Kia Soul EV	111	$ 33,950	FWD
BMW i3	114	$ 44,450	FWD
Ford Focus Electric	115	$ 29,120	FWD
Hyundai IONIQ Electric	124	$ 30,385	FWD
Volkswagen e-Golf	125	$ 30,495	FWD
Nissan LEAF	151	$ 29,990	FWD
Tesla Model 3 Standard	220	$ 35,000	AWD
Tesla Model X 75D	237	$ 84,000	AWD
Chevrolet Bolt EV	238	$ 37,495	FWD
Tesla Model S 75 D	259	$ 78,000	AWD
Tesla Model 3 Mid-Range	260	$ 46,000	AWD
Tesla Model X 100D	295	$ 99,000	AWD
Tesla Model 3 Long Range	310	$ 53,000	AWD
Tesla Model S 100D	335	$ 96,000	AWD

Figure 14: Available BEVs in the United States. (Drive Change. Drive Elecric 2018)

Figure 15 shows the percentage of NH commuters that could travel in each BEV model for their daily commute. A 15 mile buffer range was removed from each vehicle range to account for emergencies, traffic, or quick detours. This buffer could also account for winter conditions, but each battery type and size will be affected to varying degrees in the winter. *Commute In* percentages were based on the number of New Hampshire residents commuting to the Lebanon NH-VT MicroNECTA (NH Portion) from other New Hampshire labor markets. *Commute Out* percentages are based on the number of Lebanon NH-VT MicroNECTA (NH Portion) residents commuting to other New Hampshire labor markets.

As stated above, NH residents have more BEV options for lease or purchase if there is charging at their workplace for a one way trip. Figure 15 also shows the various make and model options that could support Lebanon residents commuting to labor markets in New Hampshire. For example, the Nissan Leaf has an advertised 151 mile range. If you subtract a 15 mile buffer that leaves a 136 mile range. Based on commuter data 100% of commuters in New Hampshire traveling to the Lebanon MicroNECTA could travel one-way on one full charge and approximately 87% of commuters could make a round trip commute on one full charge in a Nissan Leaf.

Comparing Figure 13 to the Vehicle Range Figure 15, all BEVs available in the U.S. could satisfy the one-way commuting mileage of residents living and working in the NH Portion of the Lebanon NH-VT MicroNECTA without a recharge. Additionally, all BEVs could satisfy a round-trip commute without a recharge, except for the smart ED when commuting to farther destinations such as Piermont. These calculations also include a 15 mile buffer for emergencies, traffic, and detours.

			Commute In		Commute Out	
	Range	Range - 15 for Buffer	% of Commuters that could travel On- way on Charge	% of Commuters that could travel Round Trip on Charge	% of Commuters that could travel On-way on Charge	% of Commuters that could travel Round Trip on Charge
smart ED	58	43	77.1%	0%*	73.8%	0%*
BMW i3s	107	92	97.7%	77.1%	97.9%	73.8%
Kia Soul EV	111	96	97.7%	79.9%	97.9%	74.3%
BMW i3	114	99	99.1%	79.9%	97.9%	74.3%
Ford Focus Electric	115	100	99.1%	79.9%	97.9%	74.3%
Hyundai IONIQ Electric	124	109	99.5%	80.8%	99.1%	75.3%
Volkswagen e-Golf	125	110	99.5%	80.8%	99.1%	75.3%
Nissan LEAF	151	136	100%	86.9%	100.0%	87.0%
Tesla Model 3 Standard	220	205	100%	99.5%	100.0%	98.2%
Tesla Model X 75D	237	222	100%	99.5%	100.0%	99.1%
Cheverolet Bolt EV	238	223	100%	99.5%	100.0%	99.1%
Tesla Model S 75 D	259	244	100%	99.8%	100.0%	100%
Tesla Model 3 Mid Range	260	245	100%	99.8%	100.0%	100%
Tesla Model X 100D	295	280	100%	100%	100.0%	100%
Tesla Model 3 Long Range	310	295	100%	100%	100.0%	100%
Tesla Model S 100D	335	320	100%	100%	100.0%	100%

*Numbers are calculated based on the average miles and assumption that commuters are traveling to and from the center of each labor market.

Figure 15: Percentage of NH residents commuting into and out of the NH Portion of the Lebanon NH-VT MicroNECTA and BEVs that support commuting range (Drive Change. Drive Elecric 2018) (New Hampshire Employment Security 2010)

This range analysis shows three things. First, a variety of BEVs exist that would support commuting distances for people commuting into and out of Lebanon. Second, BEVs exist that could support many Lebanon residents that commute to destinations inside and outside of the City for work on a round-trip basis which could encourage residents to purchase EVs. Lastly, the analysis highlights the importance of EV infrastructure at workplaces. While many commuters coming into the Lebanon area could complete their travels on a round-trip charge, many more BEV options would be available to residents if charging is available at their workplace.

Seasons

When it comes to geography and seasons, Vermont and New Hampshire are famous for year-round outdoor tourism. The geography of the two states ranges from low-lying lakes and river valleys to the tall Green Mountains in Vermont and White Mountains in New Hampshire. When it comes to driving through the various geographies, winter weather can be the most challenging aspect. Drivers in the Upper Valley often live on hillsides or mountains and frequently travel dirt roads in rural areas. Vehicles with all-wheel drive (AWD) are favorable to these drivers.

When it comes to EVs and the seasons, many consumers are concerned with battery life in cold weather and AWD traction on roads. Below is a list of impacts of EVs in winter months.

- **Batteries and Extreme Cold:**
    - All batteries are known to be less effective in extreme cold because cold temperatures impact the electro-chemical reactions within the cell, and technologies within the vehicle are designed to manage the battery and limit the charging rate to avoid damage of the battery (Motoaki 2018).
    - Ranges can be seen decreasing in extreme cold typically below 15˚F
    - New Hampshire's average temperature for its coldest month, January, is 20.5˚F. While extreme temperatures do occur in New Hampshire, its average coldest temperatures are above 15˚F (U.S. Climate Data 2018).

- **EVs will have no trouble starting:**
    - Some ICE vehicles take time to start and warm up the engine and the cabin of the car in cold months, whereas, EVs will start instantaneously and provide heat to the cabin on start (Clean Technica 2018).
- **Traction and Snow:**
    - EVs tend to have a big wheel diameter and low center of gravity with a 50/50 weight balance which can be better for traction (Clean Technica 2018).
    - Many EV models have FWD and AWD options that support better handling in slippery conditions (Clean Technica 2018).

While range and charging may be a barrier to long-distance travel on the extreme cold days in New Hampshire, other EV features are comparable and in some cases more beneficial than ICE vehicles. The potential reduced range during extreme cold temperatures is a good example of why workplace charging is highly impactful.

BEVs and Affordability

Figure 16 describes a cost comparison of three common make and model types available in the U.S. that have a comparable ICE model. The comparison has the MSRP cost for base models of both the ICE and the BEV models and with the cost difference identified. In all three cases, the BEV is more expensive leading to the assumption that many cost-conscious customers would shy away from EVs due to the cost.

Make/Model	Cost Base BEV	Cost Base ICE	Difference in Cost
Ford Focus	$ 29,120	$ 17,950	$ 11,170
Volkswagen Golf	$ 30,495	$ 21,845	$ 8,650
Kia Soul	$ 33,950	$ 16,490	$ 17,460

Figure 16: Vehicle Costs (Drive Change. Drive Elecric 2018)

Figure 17 calculates the cost difference accounting for the Federal EV Tax Incentive of $7500 and potential municipal incentives. While each scenario still leaves the cost of base BEVs higher than the base ICE vehicles, the difference is brought significantly down after the various tax incentives. For example, if Lebanon chooses to provide a tax rebate of $500 to all new EV registrants it would cost $50,000 for 100 new EVs which would be a 455% increase in EVs in Lebanon (New Hampshire Department of Motorvehicles 2017).

This calculation does not include fuel cost savings over the life of the vehicle which ranges from 3.8 cents per mile to 4.7 cents per mile for the vehicles listed (US Department of Energy 2018).

Make/Model	Cost Base Model BEV	Cost Base Model ICE vehicle	Difference in Cost	Subtract Federal Tax Incentive of $7500	Possible City Incentive of 250	Possible City Incentive of 500	Possible City Incentive of 750	Possible City Incentive of 1000
Ford Focus	$29,120	$17,950	$11,170	$3,670	$3,420	$3,170	$2,920	$2,670
Volkswagen Golf	$30,495	$21,845	$8,650	$1,150	$900	$650	$400	$150
Kia Soul	$33,950	$16,490	$17,460	$9,960	$9,710	$9,460	$9,210	$8,960

Figure 17: Vehicle Costs with Tax Incentive (Drive Change. Drive Elecric 2018) (FuelEcoconmy.Gov 2018)

Results

1. **EVs are viable in New Hampshire Geography, Seasonality, and Range for Rural Commuters**

Based on the analysis, current BEV technologies exist that could support drivers in rural areas like Lebanon. There are models available that feature AWD options for winter weather or difficult geography and dirt roads. There are a variety of vehicles with battery ranges that could support many of the State's commuters traveling into and out of the City, even in the wintertime. Battery and BEV technologies continue to be improved and researched, leading to more make and model options and a more competitive and comparable market to ICE vehicles. Research and development of battery technology for low-temperature performance would increase the reliability of the estimated charge mileage.

2. **Investing in Charging Equipment Will Have Benefits**

Charging station technologies continue to develop and grow across the country. A lack of charging infrastructure is the greatest barrier to New Hampshire and Lebanon's progress in reaching EV goals. An increasing in charging infrastructure that could mirror Vermont and Massachusetts could bridge this gap.

3. **Costs of EVs are Decreasing and Federal Tax Incentive Helps Make EVs Affordable**

Affordability could be an issue for some consumers, but the Federal Tax Incentive decreases the impact of the cost premium for BEVs. State or municipal incentives would further drive the cost down, leading to more EV purchases.

Conclusions

It is now well-known that there will be a rise in EV purchases across the U.S. Compared to ICE vehicles, EVs are fuel efficient, pollute less, and have higher fuel cost savings. This paper demonstrates that current EV technologies have progressed sufficiently to support rural commutes and this could reassure consumers with range anxiety. With the implementation of EV charging equipment across rural areas and at employment centers, more commuters will be able to comfortably purchase EVs that support a long commute with many make and model options. Improvements in battery technologies for lower temperatures have made EV implementation in colder geographies a possibility. Financial support to bring costs down combined with long-term fuel and maintenance cost savings make purchasing EVs more feasible for drivers. Market competition and various Federal and State policies have driven the market to have more make and model variety for consumer preferences.

In order to keep up with sales, States and Municipalities need to become involved through policy. The City of Lebanon promotes this transition through its support of the Paris Agreement and its approval of the Lebanon Master Plan that includes EV equipment. Based on the results derived from this paper, current EV and EV infrastructure is feasible for a rural City, like Lebanon, to succeed in this transition. Through a combined strategy of policy changes, the City can succeed in its goals to reduce greenhouse gas emissions and support EVs in the City.

Policy Recommendations

It is recommended that policies regarding EV purchases and policies regarding EV charging equipment work together to help reach EV goals. As explained in the Data section of this paper, the States of Vermont and Massachusetts have surpassed New Hampshire in public EV charging equipment as a result of multiple policies that each State has put forth. Below are three policy recommendations that are suggested for the City of Lebanon, New Hampshire.

Recommendation A:

Lebanon should require new and incentivize current employers to have charging equipment for employees. Massachusetts has a policy that suggests charging equipment for employers of 15 or more (National Conference of State Legislatures 2017). Assuming a driver could fully or partially charge their vehicle during work hours, having charging equipment at workplaces would allow 100% of New Hampshire residents working in the NH Portion of the Lebanon NH-VT MicroNECTA to purchase BEVs based on range and mileage.

Examples of EV infrastructure incentives could be through grant programs like in Massachusetts, or through site regulations for new businesses and commercial development.

Recommendation B:

Lebanon should support residents in purchasing EVs through a financial incentive in the form of a rebate or registration discount to help decrease the cost of EVs. Figure 20, describes four options of \$250, \$500, \$750, \$1000 incentives.

Examples of purchasing incentives could be emissions registration discounts at registration, emissions discounts at inspection, or rebates for EV purchases. The City could choose a one time rebate or an annual smaller rebate over time.

Recommendation C:

The City should invest in public EV Charging infrastructure on City property and private property. The City could work with the local utility, Liberty Utilities, to create the best atmosphere for connecting to the grid.

Examples on City property could be located at municipal buildings for employees as well as municipal parking lots. DC fast chargers located at short term parking lots and level 2 chargers at long-term parking would be advised. This could be achieved through Capital Improvement Funds or the City could seek grant funding such as Volkswagen funds.

The City should also work with shopping centers and commercial property owners to build charging infrastructure for shoppers and tourists. DC Fast Chargers would be advised in these locations as they have short charging times for shorter stops at stores. This could be achieved through site plan regulations or through grant programs from the City.

Abbreviations

BEV – Battery Electric Vehicle

EV – Electric Vehicle

ICE – Internal Combustion Engine

LMA – Labor Market Area

MicroNECTA – Micro New England City and Town Area

NH- New Hampshire

NOx – Nitrous Oxide

PHEV – Plug-in Hybrid Electric Vehicle

VMT – Vehicle Miles Traveled

VT – Vermont

ZEV – Zero Emissions Vehicle

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